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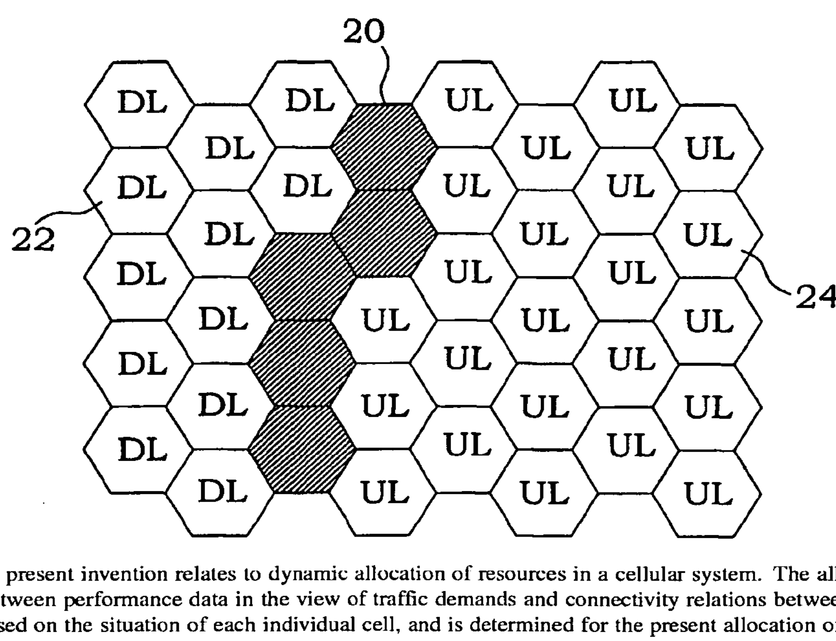
(54) **Title:** DYNAMIC UPLINK AND DOWNLINK RESOURCE ALLOCATION



(57) **Abstract:** The present invention relates to dynamic allocation of resources in a cellular system. The allocation is performed as a compromise between performance data in the view of traffic demands and connectivity relations between the cells. The performance data is based on the situation of each individual cell, and is determined for the present allocation of resources as well as other candicates of new allocations of resources. An examination is performed to find out if there exists a configuration of cells with adapted resource allocation that fulfills two criteria; that no cells within interference distance have allocated one and the same resource in opposite directions, and that the total performance of the new configuration is beneficial in relation to the earlier one. Barring is preferably used to avoid interference. If the two criteria are fulfilled a change in allocation is performed. The procedure is preferably repeated intermittently.

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DYNAMIC UPLINK AND DOWNLINK RESOURCE ALLOCATION

TECHNICAL FIELD

The present invention generally relates to bandwidth adaptation in communication systems and in particular to dynamic resource allocation in cellular systems using time division duplexing.

BACKGROUND

A typical cellular communication system provides a two-way communication between a plurality of base stations and a number of mobile stations. Transmissions from the base station to the mobile unit are commonly referred to as downlink transmissions, and transmissions to the base station from the mobile unit are commonly similarly referred to as uplink transmissions. The uplink and downlink transmission may be provided in different ways.

In a time division duplexing system, the duplexing is performed in the time domain. A mobile unit communicates with a certain base station of a cell using a specific radio frequency. The channel is time divided into repetitive time periods or time slots. These time slots are employed for uplink and downlink transmissions. There is thus no requirement for frequency separation between the uplink and downlink transmissions. Both the uplink and downlink transmissions occur during different predetermined time slots using the identical radio frequency.

In near future, the data traffic in the mobile networks is expected to increase significantly. The introduced data services are not necessarily symmetric between uplink and downlink. More likely, the load in the networks will be asymmetric and the degree of asymmetry will vary with time and geographic location. Thus, a system that can allocate a different amount of time slots or other resources for uplink and downlink transmission would be desirable. It

is especially valuable if each cell independently can allocate time slots for uplink and downlink transmission. This means that it is possible to increase the available time slots in one direction at the expense of the amount of time slots in the other direction. A typical example of such a system is the UMTS-TDD system.

The patents US 5,157,709 and US 5,475,868 discloses devices and methods for adaptive assignment of resources to cells in a cellular communication system. However, these documents do not disclose any information how to handle the specific properties required when adaptively allocating resources for uplink or downlink traffic.

The patent US 6,016,311 discloses methods and apparatuses for adaptive time division duplexing in a wireless system. The adaptive allocation is based on determined uplink and downlink bandwidth requirements based on present traffic demands averaged over a certain time. The ratio between the uplink and downlink requirements are used for dividing the available uplink and downlink time slots accordingly. The allocation is periodically updated to such an optimum choice.

A problem with the proposed solution is that co-channel interference may arise between different cells with differing allocation of uplink and downlink transmissions. The above problem is to a part addressed in the US patent, but is solved simply by dividing the cells into cell clusters with a common allocation configuration. Any co-channel interference at the boarders of such cell clusters is not further discussed.

In the article "Towards an Asymmetric Air Interface Protocol for Wireless Internet Access" by Ravi Jain and Li Fung Chang, in Proceedings of 8th International Symposium on Personal, Indoor and Mobile Radio Communications, Vol. 2, pp. 688-692, co-channel interference as the result of asymmetric allocation protocols are discussed. In the discussion, it is noticed that one cell having a downlink allocation may be separated from

cells having uplink allocation by introducing a guard band around the cell. In the guard band no uplink communication is permitted in the actual time slot. However, the article does not reveal any clues about how to find an appropriate allocation configuration.

SUMMARY

A general problem with solutions according to prior art is they are not suitable for solving both a reasonable dynamic resource allocation and a reduction of co-channel interference at the same time. A further problem is that there are no means for compromising between an optimum resource allocation and transmission capacity losses due to co-channel interference reduction arrangements. Yet another problem is to handle and administrate the complex connections of the properties of different cells.

The above problems are solved by methods and devices according to the enclosed claims. In general words, connectivity relations between the different cells and performance data for the cells are determined. The performance data is based on present traffic demand in each individual cell, and the performance data is determined for the present allocation of resources as well as other candidates of new allocations of resources. An examination is then performed to find out if there exists a configuration of cells with adapted resource allocation that fulfills two criteria. The first criterion is that no cells within interference distance or with an unacceptable interference, i.e. preferably a connectivity relation higher than a certain value, are allowed to exhibit allocation for transmissions in opposite directions. Barring is preferably used to avoid this. The second criterion is that the total performance of the new configuration, including the effect of the barring, is beneficial in relation to the earlier one. An important feature is here the judgement of the effect of barring, in order to find an overall beneficial configuration, in contrary to prior art, in which an optimum solution for one cell or a cell cluster with the same allocation is selected. If

the two criteria are fulfilled a change in allocation is performed. The procedure is preferably repeated intermittently.

In order to reduce the complexity of the examining process, the allocation for uplink and downlink communication is preferably changed at most one unit in each repetition. Furthermore, the threshold value for connectivity relations to be counted as interference is preferably zero, and the gain in performance data is preferably higher than zero, even if a high threshold may be used for introducing hysteresis effects in easily influenceable systems. It is thus not necessarily an optimum allocation configuration that is selected at once, but through the repetition of the examination, the configuration is moved towards an optimum.

In one embodiment, the examination is performed in a centralized means, gathering information from the whole system, and distributing re-allocation demands to requested cells. However, in order to reduce the complexity of the examining, a stepwise changing algorithm based on locally examined conditions is to prefer. In such a preferred embodiment, a cell collects connectivity data and performance data from its interfering neighbor cells. An examination of a local change of allocation of the cell is performed, by taking into account the losses of transmission capacity that is introduced by barring interfering cells. A change in one cell will increase the probability for a similar change in a neighboring cell, whereby the areas of different allocation slowly will move in space in order to adjust for changing transmission requests.

The advantages with the present invention is that the benefits of an asymmetric allocation of uplink and downlink transmissions can be utilized without jeopardizing the communication due to co-channel interference. Furthermore, the process is preferably conducted in such a way that limited amount of measurements, data communication and optimization capacity is requested. The asymmetric allocation is also performed repetitively, in order to adapt to present traffic demands as well as to new allocation

configurations. The present invention provides a compromise between traffic utilization and interference risks. The allocation is performed dynamically during running of the system.

Further advantages will be obvious by reading the following detailed descriptions of a number of embodiments. However, the scope of the invention should only be determined by the claims and should not be restricted to the actual described embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

FIG. 1a is a schematic drawing illustrating interference in uplink traffic in a symmetric system;

FIG. 1b is a schematic drawing illustrating interference in downlink traffic in a symmetric system;

FIG. 1a is a schematic drawing illustrating interferences in an asymmetric system;

FIG. 2 is a schematic drawing illustrating interfering cells in a cellular system;

FIG. 3 illustrates schematically the allocation of resources in a two-dimensional array of cells according to the present invention;

FIG. 4 illustrates schematically the allocation of resources in a cross section of an array of cells according to the present invention;

FIG. 5a illustrates the allocation for a certain resource for an array of cells according to the present invention, having one downlink allocation;

FIG. 5b illustrates the allocation for a certain resource for an array of cells according to the present invention, having several uplink allocations;

FIG. 6a illustrates a flow diagram describing a method for adaptive resource allocation according to the present invention;

FIG. 6b illustrates a flow diagram describing a method for adaptive resource examination according to the present invention;

FIG. 7 illustrates a mobile telecommunication network in which the present invention may be applied;

FIG. 8a illustrates a communication network employing centralized adaptive resource allocation according to the present invention;

FIG. 8b illustrates a communication network employing distributed adaptive resource allocation according to the present invention;

FIG. 8c illustrates the data flow in a distributed adaptive resource allocation according to the present invention; and

FIG. 9 illustrates a typical example of the gradual development of adaptive resource allocation, resulting from a distributed adaptive resource allocation.

DETAILED DESCRIPTION

In the present invention, "resource" is used to denote any reservable communication unit used for communication, such as time slot, frequency, code or any combination of these. Further, a resource can normally be reused several times throughout a system, which makes the resource usage strongly connected to the geographic location. Examples of systems using these concepts are DECT (TDD FD-TDMA), UTRA-FDD (FDD CDMA), UTRA-TDD (TDD TD-CDMA) and GSM (FDD FD-TDMA).

A cellular communication system comprises a number of cells, covering a certain geographical area. Within each cell, a base station conducts communication operations with a number of mobile stations. In order to cover an area completely, a certain overlap of the cell areas has to exist, and even where the signal strength from a base station is too low for a reliable communication, disturbances may arise. Fig. 1a illustrates two base stations BS1 and BS2. Two mobile stations MS1 and MS2 are present in the area in the vicinity of the base stations. At the moment BS1 handles the communication to MS1 and MS2 is connected through BS2. Certain communication resources, such as e.g. time slots, are allocated for uplink

traffic and certain other resources are allocated for downlink traffic. This allocation is in a traditional cellular system constant and equal for each cell. As illustrated in fig. 1a, MS1 communicates in a resource allocated for uplink communication with the base station BS1 and MS2 in a similar way with BS2. The signals sent from MS2 may also be detected as an interference signal MBI by BS1. The MBI interference is a so-called mobile-to-base interference.

Fig. 1b illustrates a similar case, where downlink traffic is sent in a certain allocated resource from BS1 and BS2 to MS1 and MS2, respectively. Interference BMI is also here possible, since the signals from e.g. BS2 may be detected also by MS1, a base-to-mobile interference.

Such base-to-mobile and mobile-to-base interferences are well known and treated by the present systems in well known manners.

Fig. 1c illustrates a situation, where two base stations within interference distance of each other have different allocations of its resources for uplink and downlink communication, respectively. New interference situations will thereby be present. In the illustrated case, MS1 communicates with BS1 in a certain resource, which is allocated for uplink communication within the cell of BS1. However, the same resource is allocated for downlink communication in the cell of BS2, whereby BS2 may send signals to MS2 at the very same resource. Two new interference types are here present. A base-to-base interference BBI occurs when e.g. BS1 receives signals from BS2, and a mobile-to-mobile interference MMI occurs when e.g. MS2 picks up signals from MS1. These interferences only occur when the resource allocation is different in cells within interference distance to each other.

A base-to-base interference BBI is normally static, in that sense that the signal strength from the base station BS2 typically is constant or at least within a certain dynamical power range and the transmission conditions to BS1 are normally rather constant, since the base stations are geographically

fixed with respect to each other. Interferences may be measured and/or precalculated. However, since the transmission strength of a base station typically is much larger than from a mobile station and that line of sight often is present between base stations, the BBI interference signal may even dominate over the actual uplink UL signal. Compensations for such interferences may be possible to perform due to the known behavior.

A mobile-to-mobile interference MMI is more rare, since the transmission strength of a mobile station is typically much less than for a base station. In order for the interference to be noticeable, the mobile stations have to be situated geographically close to each other. The MMI interferences are thus normally less serious in that sense that it only occurs with a small probability. However, since they depend on the relative locations of the mobile stations, MMI interferences are not constant in time but rather stochastic, which means that when occurring, they are extremely difficult to compensate for and therefore quite severe.

Fig. 2 is a schematic drawing of a cellular system 10. A number of cells 12 are arranged to cover (most of) a certain geographical area. (Only one item of each is numbered in order to increase the readability of the figure.) Each cell 12 has a certain coverage, depending of transmission strengths and/or transmission conditions, schematically indicated by the border of the ellipse. Each cell 12 has a base station 14 (only one is illustrated). Each of the base stations is within interference distance with a number of other base stations. For the cell with the illustrated base station 14, there are four interfering cells, marked with a hatching. When discussing "surrounding" interfering cells, the word should thus not be considered in a purely geographical sense, but more as a combination of transmission conditions and spatial relationships. The important issue is if the cells may interfere with each other.

One of the main issues of the present invention is to provide means for avoiding interference, in particular mobile-to-mobile interference and base-

to-base interference, when applying an adaptive resource allocation. A basic idea is to prevent use of cells within interference distance in which the same resource is allocated differently. This prevention may preferably be performed by barring the resource in question for any communication in a cell between the cells with different allocation. In other words, in respect of a specific resource, each cell with an allocation in a first direction is only surrounded within interference distance by cells with an allocation in the same first direction or barred cells. An alternative way to consider it is to say that, in respect of a specific resource, two cells having different allocation should not be able to interfere with each other. Cells being within interference distance with cells having opposite allocation should preferably be barred.

Fig. 3 shows a schematic illustration of a cellular system. Each cell is represented by a hexagonal stack. Each cell is assumed to be within interfering distance with all direct neighbors, but no others. The vertical dimension represents the resources for transmissions. A number of resources are allocated for downlink traffic (DL), positioned at the bottom of the stack. A number of resources allocated for uplink traffic (UL) are positioned at the top of the stacks. In this explanatory example, the total number of resources are 8. The number of uplink resources are shown by the figures on top of each stack. From fig. 3 it is seen that the number of uplink resources varies throughout the system between 2 and 5. Barred, i.e. unused resources are marked as hatched.

Fig.4 is an illustration of a similar cellular system, shown in a vertical section, i.e. only one spatial dimension is illustrated. The vertical dimension is still representing the different available resources. Here it is easily seen how the number of uplink and downlink resources are varying throughout the cellular system. Here it is easily seen that the dynamical allocation can extend over several resources in different areas of the cell system. Barred resources are marked as hatched.

Fig. 5a instead represents a horizontal section of system similar to the one shown in fig. 3. Here the spatial directions are shown, and since the section is made through a specific resource, the allocation for this resource is marked as uplink (UL) 24, downlink (DL) 22 or barred 20 (hatched). Fig. 5a describes a case, which probably is not particularly advantageous. One cell 22 has the resource allocated for downlink communication, whereas in most of the other cells, the resource is allocated for uplink 24 communication. The four cells 20 within interfering distance of the downlink cell are barred. In this manner, no interference occurs between the uplink 24 and downlink 22 cells. Any advantage of having the single DL allocation compared with uplink must exceed the disadvantages of barring the four surrounding cells. However, this may be the situation, if the surrounding cells are presently not in use, or if the importance of having the DL allocation of the resource is much higher than the absence of the four UL resources.

In fig. 5b, the advantages with the algorithm according to the present invention is more clear. Here, 12 cells have a downlink allocation. The total benefit in having DL allocation instead of UL may be summed over the 12 cells. This total benefit can in many cases easily compensate for the disadvantage of unavailable resources of the barred cells, in this case 5. The relative importance of the barred cells will generally decrease with size of the area changing its allocation.

In short, a procedure for adaptive resource allocation according to the present invention is illustrated by the flow diagram of fig. 6a. The procedure starts in step 200. In step 202, performance data is determined for different possible allocation configurations. The performance data reflects the benefit of the system in the view of the present traffic situation and traffic demands. The performance data may be determined in different measures, e.g. mean delay time, maximum buffer length, throughput or blocking. Changing an uplink allocation to a downlink allocation may increase the performance of the whole system if there is a need for more downlink resources due to the present traffic demands. However, the performance may also decrease if

such a reallocation will reduce uplink resources, which already are fully utilized. However, performance data for different allocation configurations of the system are determined. Since the number of all possible allocation configurations in a real system often is huge, some sort of restriction normally has to be introduced. A natural restriction of investigated allocation configurations is to only consider allocation configurations, where the number of uplink resources and the number of downlink resources do not differ by more than one, as compared with the present configuration. In other words, this means that for every possible reallocation, the number of downlink resources and the number of uplink resources do not change more than one step. If a further advantageous configuration demands a change of more than one step, the entire examining procedure can instead be repeated. The provision of performance data is discussed more in detail further on.

Step 204 comprises a determination of connectivity relations between cells in the cellular communication system. Connectivity relations reflect the mutual relation between base stations, e.g. the amount and seriousness of any interference. Such connectivity relations define the relative positioning in view of signal interference between the different cells. The details about preferred embodiments of determining the connectivity relations are described more in detail further below.

In step 206, an examination is performed, over different allocation configurations, whether two reallocation criteria are fulfilled; a total system benefit and a sufficiently low risk for interference. Preferably, the risk for interference should be non-existent. The examination of the total system benefit utilizes the determined performance data and the examination of the interference situation makes use of the determined connectivity relations. The details of preferred embodiments of this examination algorithm are described further below. In step 208 the existence of an allocation configuration fulfilling both reallocation criteria is investigated. If such an allocation configuration exists, the procedure continues to step 210, where the system is reallocated to the found allocation configuration. The

procedure ends in step 212. Note, that the selected configuration not necessarily has to be the globally optimum choice, as in e.g. US 6,016,311. The new configuration only has to be an improvement, compared with earlier allocation configuration.

In fig. 6b, a corresponding flow diagram is illustrating the actual adaptive resource examination procedure. The procedure starts in step 220. In step 222, performance data is obtained for different possible allocation configurations. Step 224 comprises obtaining of connectivity relations between cells in the cellular communication system. In step 226, an examination is performed, over different allocation configurations, whether two criteria are fulfilled; a total system benefit and a sufficiently low risk for interference. This step is parallel to step 206 in fig. 6a. The procedure ends in step 228.

The examination procedure may be performed periodically, or may be initiated when requested. A criterion for initiate the examination procedure can e.g. be that the first of the two reallocation criteria is fulfilled, i.e. that a allocation change anywhere in the system gives a probable performance gain, regardless of the connectivity situation.

The present invention is applicable to many different fields, involving cellular communication systems. A first application example, illustrated in fig. 7, is a mobile system according to the UMTS standards. See e.g. the standardizing documents 3GPP TS 25.201 "Physical Layer - General Description" and 3GPP TS 25.301 "Radio Interface Protocol Architecture" describing UTRA-TDD. A cellular system 44, comprises a central unit 30 connected to other communication networks by a connection 40. The central unit is in turn connected to local units 32, by connections 38. The local unit 32 has in turn a number of base stations 34 (of which only one is numbered in order t make the figure easier to understand) connected to it. Each base station is responsible for a cell 42 and communicates by radio communication with a number of mobile stations 36 present in the respective cell. As can be seen

from the figure, the cells overlap and interference may occur between certain combinations of cells. The present invention may be beneficially applied to such a communication system.

Fig. 8a illustrates a first embodiment of a cellular communication system according to the present invention. A number of base stations 34 are connected to a central examination means 46 by connections 48. The base stations are provided with means for determining performance data concerning its own cell. This means that each base station 34 evaluates its present traffic situation and determines what consequences will result from a change of resource allocation.

As a further example, the base station may e.g. have a high amount of downlink traffic buffered, but very little uplink traffic, causing long downlink time delays and long downlink buffer lengths. A reallocation giving more downlink allocated resources will be of benefit for this individual base station. Furthermore, a barring of some of the uplink resources would not give any significant change of the performance, since these resources anyway was not utilized. In this situation, the base station can evaluate that an increase in downlink resources is beneficial, and a decrease in downlink resources is disadvantageous and that any small change in uplink resources will not matter at all. Such information is sent to the central examination means 46. The performance data from one individual base station may be used to initiate the evaluation procedure. If there is an advantage in changing the allocation in one single cell, there might be a chance that there exist a configuration fulfilling the reallocation criteria.

The base station 34 may also provide information about the connectivity relations of the system. The base stations 34 preferably comprises means for determining interference signal strengths from other cells, in particular base-to-base interference and preferably also mobile-to-mobile interference. This information is collected, processed and connectivity data concerning the base station in question is sent to the central examination means 46.

The central examination means 46 thus collects performance data and connectivity relations from the different base stations 34 and processes the data to gain a total view of the state of the whole communication system. The central examination means 46 examines the situation and if a better allocation configuration exists, the central examination means 46 distributes reallocation demands allover the system. The corresponding reallocation of resources follows, according to reallocation methods according to prior art.

Having the entire information of the system, a total view can be applied. Such a total view will comprise a huge number of possible configurations, even with the ±1 limitation (the limitation described above of changing the number of uplink or downlink resources by at most one unit). The computation has in practice to be simplified by using different algorithms, sorting away non-probable configurations in an efficient manner. The examination may e.g. be facilitated by algorithms minimizing the total number of barred resources in the system, under the condition that the second reallocation criterion still is fulfilled.

The centralized approach as presented above will certainly be operable, but has certain minor disadvantages, in particular in the huge amount of data to process. A preferred embodiment of the present invention is instead presented in fig. 8b. A certain base station 34 may as described above be provided with means for determining the connectivity relations with its neighboring base stations. If a change in allocation occurs in one single base station, only the relation between this base station and its interfering neighbors will be influenced. This is the basis of the distributed embodiment of the present invention illustrated in fig. 8b. A base station 34 has means for examining 50 of the existence of an adapted allocation configuration fulfilling the reallocation criteria. The base station in question supplies information about its own performance data and connectivity relations. According to the connectivity relations, performance data and preferably also connectivity relations are requested from base stations having a connectivity

relation with the base station in question exceeding a certain threshold, preferably zero. In such a way, the distributed means for examining 50 will have information about performance and connectivity in the vicinity of the own base station. The means for examining 50 examines the existence of a local allocation change within the area of the base stations from which information is requested, which fulfills the reallocation criteria. If such a configuration exists, demands for reallocation is distributed from the means for examining to the base stations concerned by the reallocation.

Fig. 8c illustrates the data flow in the process. Performance y_j data are communicated to a first base station i from the remaining base stations j, regarding the performance situation of each individual base station. Also connectivity relations c_{ij} concerning the relation between the first and the remaining base stations are preferably collected. The examining means of the first base station i evaluates the information, and if an advantageous reallocation is found, demands are communicated to the concerned base stations.

An example of a situation will be described in connection with fig. 9. Assume that a certain communication resource, e.g. a time slot, is allocated for uplink communication in all cells. This is illustrated in the upper left part of the figure. In one of the leftmost cells, there is a request for more downlink capacity, which means that a reallocation of this resource to downlink traffic would give an advantage for the cell in question. The examination starts, and data is brought in from the cells within interference distance. Since the resource in all these cells also is in allocated for uplink traffic, these cells have to be barred. The performance data for a barred allocation of these four cells is calculated and compared with the performance data for the present situation. It is concluded that the disadvantage, if any, of barring the four surrounding cells is less than the benefit appearing from changing the original cell from uplink allocation to downlink allocation. An allocation configuration fulfilling both reallocation criteria is now found. A reallocation thus takes place, resulting in the situation of the upper right part of fig. 9,

i.e. a reallocation of one cell from uplink to downlink traffic and barring the four surrounding cells from any traffic. The reallocation is demanded from the central cell.

The example continues with the fact that one of the barred cells, the one in the lower left corner, finds out that it should benefit from changing its allocation state from barred into a downlink configuration. It requests data from the base stations within interference distance, i.e. the three surrounding cells. The cell evaluates the own benefit and compares it with the disadvantage for the surrounding cells if they are going to fulfill the second reallocation criterion, i.e. non-interference. In this case, one of the neighbors has already a downlink allocation and no change is necessary. Another is barred, which also is according to the second reallocation criterion, and no change is necessary. However, the third neighboring cell has an uplink allocation and has to be barred to fulfill the criteria. The disadvantage of barring this cell shows to be less than the benefit of changing the lower left cell to a downlink allocation. A reallocation is then performed, demanded by the new central cell, which reallocation results in the situation illustrated in the lower right part of fig. 9.

From this it is seen that if a benefit for a change in a central cell is detected, the disadvantage for barring all neighboring cells having the opposite allocation is evaluated. Barred cells or cells with the same allocation do not need to be considered. If the benefit is larger than the disadvantages, a reallocation takes place.

One also understands that a reallocation is easiest performed at the border between an area of uplink and downlink allocations. The first reallocation normally has a certain inertia to be performed, but when the first reallocation once is performed, following neighboring reallocations are facilitated. This leads to the effect of a successive moving of the barred border between the two allocation domains. In the example, three further reallocations may lead to the situation illustrated in the lower left corner of

fig. 9, where the border between uplink and downlink allocation has been moved further. In this way, a whole area may eventually be reallocated from uplink to downlink.

The corresponding procedure will of course take place, when reallocating from downlink to uplink.

This action may also be described in mathematical terms. The base stations provides performance data connected to alternative allocation schemes. If a cell has N resource units, and n^{UL} presently are allocated for uplink traffic, n^{DL} presently are allocated for downlink traffic, $n^{B} = N - n^{UL} - n^{DL}$ resources are barred.

A performance index exists for all cells in the system. The performance index for each cell of the present allocation is denoted y^{0}. Performance indices are estimated also for four other configurations, namely a configuration with one more uplink allocation, one less uplink allocation, one more downlink allocation and one less downlink allocation in that particular cell. The corresponding performance indices are denoted y^{UL+}, y^{UL-}, y^{DL+} and y^{DL-}. If n^{B} originally is zero, $y^{UL+} = y^{DL-}$ and $y^{UL-} = y^{DL+}$, otherwise they are uncoupled. Since differences are of importance, the differences $\Delta y^{UL+} = y^{UL+} - y^{0}$, $\Delta y^{UL-} = y^{UL-} - y^{0}$, $\Delta y^{DL+} = y^{DL+} - y^{0}$ and $\Delta y^{DL-} = y^{DL-} - y^{0}$ are calculated. These four differences constitutes the necessary relevant performance data for this preferred embodiment. The preferred way to calculate the performance indices is described below.

If any of the differences (normally Δy^{DL+} or Δy^{UL+}) is larger than a certain initializing threshold value, preferably zero, an examination procedure is initiated by the base station, concerning the reallocation of resource $n^{DL} + 1$ to a downlink allocation respectively resource $N - n^{UL} - 1$ to an uplink allocation. (The downlink allocations are always assumed to be placed at the

first resources and the uplink allocations at the last resources, having any barred resources inbetween.)

The base station initiating the examination, denoted by i, determines connectivity relations c_{ij} to neighboring base stations j. The connectivity relation c_{ij} is associated with the degree in which communication from the different surrounding base stations j interferes with the communication of base station i. From the c_{ij}, where $j = 1 \ \ldots \ n_j$, i.e. the number of other base stations, base stations within interference distance can be extracted by selecting the c_{ij} having a value larger than an interference threshold, preferably zero.

The selected interfering neighbors are requested to send performance indices or differences thereof (Δy_j) and preferably also connectivity data c_{ji}, i.e. the degree in which signaling from base station i or its mobile stations are interfering with the signaling within cell j.

A gain g_i is set to Δy_i^{DL+} or Δy_i^{UL+}, depending on which difference initiated the examination. In the following description of this preferred embodiment, a gain in increasing the number of downlink allocations is discussed. An increase of uplink allocations will be analogous. The gain is thus:

$$g_i = \Delta y_i^{DL+} \quad .$$

In a similar way loss l_i is calculated as the sum

$$l_i = \sum_{j \ \left(c_{ij} > \xi, n_j^{UL} \geq N - n_i^{DL}\right)} \Delta y_j^{UL-} \quad ,$$

where ξ is a small interference threshold, preferably equal to zero. That is, the sum is calculated over all interfering neighbors having uplink allocation. The total benefit of a reallocation will be obtained as:

$$G_i = g_i - l_i \; .$$

If $G_i > 0$, the proposed allocation is favorable and a reallocation is demanded by base station i. Base station i will itself reallocate, by increasing the number of downlink allocations by one. Only the base stations involved in the sum above will be demanded to reallocate, which in this case means a barring of a previous uplink allocation.

The formulas above may be modified in different manners in order to comply with different additional requests. One possible behavior of a system according to the present invention could be that the system oscillates forth and back between two different, but equally valuable configurations. There are basically two ways of damping such oscillations, by introducing hysteresis effects. One possibility is to use an initiation threshold larger than zero. In such a case, a small benefit will not initiate any examination at all. Another possibility is to use a relation

$$G_i > \zeta \, ,$$

where ζ is a small number. The total gain thus has to be somewhat larger than zero before a reallocation may take place.

However, introduction of hysteresis terms may also have drawbacks. Since the first reallocation of a certain resource in average is more difficult to perform, there is a certain risk, in particular if hysteresis terms are used, that no reallocation at all takes place. This may be cured by using negative hysteresis terms, or adding a term to the total gain G_i that will depend on

the relative sizes of the uplink and downlink areas for the resource in question.

$$G_i = g_i - l_i + A\left(n^{\Sigma UL}, n^{\Sigma DL}\right) \quad ,$$

where A depends on the number of uplink allocations $n^{\Sigma UL}$ and downlink allocations $n^{\Sigma DL}$ for the resource in question. A first reallocation may thereby be favored by selecting the proper function A.

In the preferred embodiment, the interference threshold ξ is equal to zero. However, if the connectivity relations are accurately graded, a small risk for interference may be allowed in order to reduce the computational complexity. The magnitude of ξ can be set to adjust the compromise between traffic demands and interference.

If a system has e.g. an overall high load of downlink traffic during a period, the present invention will drive the system to allocate more downlink resources. If the load is reduced, and no uplink load immediately restores the allocation situation, the system will probably remain in the highly unsymmetrical allocation configuration, since there is no real driving force to restore the system. However, when an uplink load appears, there will be a certain inertia in the system, before it has time to adjust to the new situation, and unnecessary performance degradation may occur in the meantime. In such cases, a mechanism for restoring the system to an equilibrium configuration would be of benefit. One such modification is to add further terms into the total gain G_i.

One possibility is just to add an extra term in the relation, which depends on the total amount of asymmetry or deviation from the equilibrium of the system. There will thus be a driving force to reduce the asymmetry or deviation. If measures $\Delta n_i^{UL} = \left|n_i^{UL} - n_{i,eq}^{UL}\right|$ and $\Delta n_i^{DL} = \left|n_i^{DL} - n_{i,eq}^{DL}\right|$ are provided,

where $n_{i,eq}^{UL}$ and $n_{i,eq}^{DL}$ are the equilibrium configurations, respectively, a possible relation would look like:

$$G_i = g_i - l_i + E\left(\sum_i \Delta n_i^{UL}, \sum_i \Delta n_i^{DL}\right) \quad .$$

An alternative would be to bias the gain term g_i, e.g. according to

$$g_i = \Delta y_i^{DL+} \cdot E\left(\Delta n_i^{UL}, \Delta n_i^{DL}\right) \quad .$$

In some systems, the traffic in certain cells may be considered as more important than the traffic in other cells. A power station utilizing mobile communication for security messages or a hospital using mobile communications for transferring important information may be very sensitive to e.g. delays in the traffic. In order to ensure a high performance in these cells, a priority term may be introduced. A preferred way to introduce it into the algorithm is to let the performance index differences include a priority factor p_i, characterizing the importance of the cell i as:

$$\Delta y_i^{UL+} = p_i \cdot \left(y_i^{UL+} - y_i^0\right),$$
$$\Delta y_i^{UL-} = p_i \cdot \left(y_i^{UL-} - y_i^0\right),$$
$$\Delta y_i^{DL+} = p_i \cdot \left(y_i^{DL+} - y_i^0\right) \text{ and}$$
$$\Delta y_i^{DL-} = p_i \cdot \left(y_i^{DL-} - y_i^0\right)$$

The rest of the equations may then be unchanged. A high priority factor p_i will increase the tendency to make reallocations according to a gain in a prioritized cell, and will reduce the tendency to make reallocations, which are of detriment for a prioritized cell.

The performance index is an index reflecting the quality of the communication, in view of the present traffic situation. There are numerous

possible measures, which can be used as performance indices. For packet data services, the throughput and the delay are good measures of how the system performs. For time critical applications, such as real-time audio and video, the delay must not exceed a certain threshold, without being noticed as annoying. Further, to maximize the resource utilization, the system throughput should be high. Another one, closely related measure, would be the maximum used buffer space.

For circuit-switched services, the blocking rate in the system must not exceed a certain threshold. A connection is typically established for as long as the call lasts. If the resources are fully used, "new" users can not enter the system, i.e. they are blocked out. Users that are blocked are not satisfied, and this figure should thus be kept low. This should, however, not be allowed to influence the traffic of the users already within the system.

For both the packet and the circuit switched services, the received signal quality must be high, i.e. a low bit error rate, to assure error-free communication. Such transmission quality measures may also be used, preferably in combination with the traffic oriented measures, such as the transmission delay, cell throughput, transmission buffer length and blocking rate described further above.

The connectivity relations used in the above processes can be achieved in different manners. In one embodiment, it is possible to estimate the theoretical interference between different cells, starting out from expected load, geometrical considerations, signal strengths etc. Such estimates are probably quite rough and may not correspond very well to the actual conditions.

A better way would be to measure the interference dynamically, preferably by using the base stations and the mobile stations themselves. There are always some occasions, where there is some available free resources, which are possible to be used for interference measurements. The base stations may

e.g. be equipped with means for measuring base-to-base interferences. One base station may find a resource, which is used for downlink traffic in a neighboring cell. Information about the present allocation and traffic situation can be exchanged between the base stations. By measuring the actual detected signal strength from the neighboring base station, an interference measure can be calculated. The base-to-base interference is typically quite constant with time, but may vary due to changes in signaling strengths, radio signal transmitting conditions etc. The interferences are normalized in a suitable manner. Such relations are investigated for all other cells in the network, or at least for cells within a distance where the interference is expected to have a certain probability to exist.

The mobile stations may be used for estimating the mobile-to-mobile interference. One mobile in the own cell is used to measure the interference contribution from an uplink resource in a neighboring cell. The corresponding resource is preferably unused the own cell. Information about the present allocation and traffic situation can be exchanged between the base stations. The mobiles and resources are preferably selected in a random manner to obtain a suitable average value. The mobile-to-mobile interference may vary considerably with time, and since the occurrence is basically stochastic, a number of measurements have to be performed in order to present a fairly reliable average. The interferences are normalized in a suitable manner. Such relations are investigated for all other cells in the network, or at least for cells within a distance where the interference is expected to have a certain probability to exist.

The interference measures are filtered in a suitable way, e.g. by percintile filtering, where a representative value is determined. Such a value could e.g. correspond to 90% of the statistical distribution of the measurements. Filtered interference measures of the base-to-base and mobile-to-mobile interferences are now available. The connectivity parameters c_{ij} discussed above are discussed as being essentially one value. In order to accomplish this, a sum of the interferences, a quadratic sum of the interferences, a

weighted sum of the interferences, the maximum value etc. may be used to combine the two measures into one.

Furthermore, in a simple embodiment, a connectivity matrix is created :

$$C = \begin{bmatrix} c_{11} & \cdots & c_{1n_j} \\ \vdots & \ddots & \vdots \\ c_{n_j1} & \cdots & c_{n_jn_j} \end{bmatrix}.$$

The connectivity relation elements c_{ij} are thus associated with the degree in which signaling from the different surrounding base stations j interferes with the signaling of base station i. The elements in a row thus indicate the interference from the surroundings of a certain base station. The elements in a column thus indicates the interference caused by a certain base station to its surroundings. In a simple embodiment, the matrix is symmetrized by using transponates, so that $c_{ij} = c_{ji}$.

In a very simple embodiment, the elements in the matrix C can be given binary values, i.e. either the value "0" or the value "1", where "0" indicates a non-interfering situation, and a "1" indicates an interfering situation. The "loss equation" can then easily be rewritten as:

$$l_i = \sum_{j \ \left(n_j^{UL} \geq N - n_i^{DL}\right)} c_{ij} \cdot \Delta y_j^{UL-} \quad ,$$

since a "0" in the matrix element automatically will cancel the term for non-interfering cells.

The matrix elements can, however, be used to rate the interference in different levels or according to a continuous scale, in order to facilitate a change in the adjustment of the connectivity threshold value ξ.

When studying the problem of connectivity more carefully, one understands that there is also a possibility to treat the different interferences separately, i.e. not symmetrize the matrix C, and even give the elements c_{ij} as vectors of two values:

$$c_{ij} = \begin{bmatrix} c_{ij}^B & c_{ij}^M \end{bmatrix},$$

where c_{ij}^B is the base-to-base interference and c_{ij}^M is the mobile-to-mobile interference. Separate connectivity thresholds could then be used for the different interferences. A loss relation for reallocation to one more downlink resource would then look like:

$$l_i = \sum_{j \ \left(\left(c_{ij}^B > \xi^B \ \ or \ \ c_{ji}^M > \xi^M\right) \ and \ \ n_j^{UL} \geq N - n_i^{DL}\right)} \Delta y_j^{UL-} ,$$

(and a loss relation for reallocation to one more uplink resource would then look like:

$$l_i = \sum_{j \ \left(\left(c_{ij}^M > \xi^M \ \ or \ \ c_{ji}^B > \xi^B\right) \ and \ \ n_j^{DL} \geq N - n_i^{UL}\right)} \Delta y_j^{DL-}).$$

The examining of the existence of alternative allocation configurations is based on two criteria. Above, the evaluation of each of the criteria is performed in separate steps or by separate algorithms. It is, however, also possible to perform the evaluation by means of a single step or a single algorithm, taking care of both aspects. It would, e.g. be possible to create a single evaluation function depending on both connectivity relations and performance data. Such a function could then weight a large benefit in performance against a minor increase in the risk of interference. Thus, the possible interference should be kept at an acceptable level, at least in the view of the potential performance enhancement.

It will be understood by those skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

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CLAIMS

1. A method for adaptive allocation of resources for uplink/downlink traffic in a cellular communication system (10, 44), comprising the step of:

determining connectivity relations (c_{ij}) between cells (12) in said cellular communication system (10, 44),

characterized by the further steps of:

determining performance data (y_j) for a number of uplink/downlink allocation configurations, for each cell in a first set of cells in said cellular communication system (10, 44), based on present traffic demands regarding uplink and downlink traffic, said uplink/downlink allocation configurations comprising resources allocated for uplink communication (24), downlink communication (22) or barred (20) for any communication, said first set of cells comprising at least two cells;

examining the existence of an adapted uplink/downlink allocation configuration of a second set of cells, being a subset of said first set, based on said determined connectivity relations (c_{ij}) and said determined performance data (y_j), with which:

each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) indicating interference of an acceptable level; and

the total performance of the adapted uplink/downlink allocation configuration exceeds the total performance of the original uplink/downlink allocation configuration for said second set; and

if said adapted uplink/downlink allocation configuration exists, changing the uplink/downlink allocation configuration of said second set accordingly.

2. A method according to claim 1, **characterized in that** said step of examining comprises examining the existence of an adapted uplink/downlink allocation configuration in which each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation,

respectively, for any common resource, have a connectivity relation (c_{ij}) smaller or equal to a first threshold value ξ.

3. A method according to claim 2, **characterized in that** a first resource in a cell in said adapted uplink/downlink allocation configuration, which cell has connectivity relations (c_{ij}) to other cells that are larger than said first threshold ξ, at least two of said other cells having said first resource allocated for communication in opposite directions, is barred for any communication.

4. A method according to claim 2 or 3, **characterized in that** said first threshold ξ is zero.

5. A method according to any of the claims 2 to 4, **characterized in that**, for each cell, the magnitude of the difference between the number of resources allocated for uplink communication (n^{UL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one, and the magnitude of the difference between the number of resources allocated for downlink communication (n^{DL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one.

6. A method according to any of the claims 2 to 5, **characterized in that** said steps are repeated intermittently.

7. A method according to any of the claims 2 to 6, **characterized in that** said examining step is performed if, for any cell in said first set, a gain g_i calculated from the performance data (y_j) of the existing uplink/downlink allocation configuration and the performance data (y_j) of any other uplink/downlink allocation configuration, exceeds a first amount ζ.

8. A method according to claim 7, **characterized in that** said first amount ζ is zero.

9. A method according to any of the claims 2 to 8, **characterized by** the further step of:

communicating said determined connectivity relations (c_{ij}) and said determined performance data (y_j) to centralized allocation means (46), whereby said examining step is performed in said centralized allocation means (46); and

if said adapted uplink/downlink allocation configuration exists, sending corresponding allocation demands from said centralized allocation means (46) to each individual cell, whereby said uplink/downlink allocation configuration change is performed by each individual cell.

10. A method according to any of the claims 2 to 8, **characterized by** the further step of:

communicating, to a cell number i (50), said determined connectivity relations (c_{ij}) and said determined performance data (y_j) related to a third set of cells, comprising said i:th cell (50) and all cells having a connectivity relation (c_{ij}) with said i:th cell (50) exceeding said first threshold value ξ, whereby said examining step is performed in said i:th cell (50); and

if said adapted uplink/downlink allocation configuration exists, sending corresponding allocation demands from said i:th cell (50) to all other cells in said third set of cells;

whereby said uplink/downlink allocation configuration change is performed by each individual cell in said third set of cells.

11. A method according to claim 10, **characterized in that** said connectivity relations are provided as a connectivity matrix, where each element c_{kj} indicates the interference of communication within cell k caused by communication within cell j.

12. A method according to claim 11, **characterized in that** the values of said connectivity elements c_{kj} are binary, indicating an interfering relation and a non-interfering relation, respectively.

13. A method according to claim 11, **characterized in that** the value of each of said connectivity elements c_{kj} is an interfering probability.

14. A method according to claim 11, 12 or 13, **characterized in that** said connectivity matrix is symmetric.

15. A method according to any of the claims 10 to 14, **characterized in that** said connectivity matrix elements c_{kj} are determined by the base station of each cell.

16. A method according to any of the claims 10 to 15, **characterized in that** said performance data is a measure of at least one of the properties in the list of:

transmission delay,
cell throughput,
transmission buffer length, and
blocking rate.

17. A method according to claim 16, **characterized in that** said performance data is further dependent of at least one transmission quality measure.

18. A method according to any of the claims 10 to 17, **characterized in that** said performance data (y_j) for each cell comprises performance indices for present uplink/downlink allocation configuration y^0, for an uplink/downlink allocation configuration of one additional resource allocated for uplink communication y^{UL+}, for an uplink/downlink allocation configuration of one less resource allocated for uplink communication y^{UL-}, for an uplink/downlink allocation configuration of one additional resource allocated for downlink

communication y^{DL+}, and for an uplink/downlink allocation configuration of one less resource allocated for downlink communication y^{DL-} or data derivable therefrom.

19. A method according to claim 18, **characterized in that** said examining step is performed if, for any cell in said third set, a gain g_i calculated as the difference between the performance index y^{UL+} or y^{DL+} and the performance index y^0, exceeds a first amount ζ.

20. A method according to claim 19, **characterized in that** said examining step further comprises the steps of:

if y^{UL+} exceeds y^0:

calculating the gain g_i for changing the allocation for a resource m for said i:th cell to uplink as the difference between the performance index y^{UL+} and the performance index y^0;

calculating a loss l_i for barring resource m of all cells having a connectivity relation (c_{ij}) larger than said first threshold value ξ and having a downlink allocation, as the sum of loss terms comprising the differences between the performance index y^0 and the performance index y^{DL-} for such cells; and

examining if said gain is larger than said loss; and

if y^{DL+} exceeds y^0:

calculating the gain g_i for changing the allocation for a resource m for said i:th cell to uplink as the difference between the performance index y^{DL+} and the performance index y^0;

calculating a loss l_i for barring resource m of all cells having a connectivity relation (c_{ij}) larger than said first threshold value ξ and having a downlink allocation as the sum of loss terms comprising the differences between the performance index y^0 and performance index y^{UL-} for such cells; and

examining if said gain is larger than said loss.

21. A method according to claim 19 or 20, **characterized in that** said performance data (y_j) also include priority factors for each cell.

22. A method according to claim 19, 20 or 21, **characterized in that** said performance data (y_j) also depends on $\Delta n^{UL} = \left| n^{UL} - n_{eq}^{UL} \right|$ and $\Delta n^{DL} = \left| n^{DL} - n_{eq}^{DL} \right|$, where n^{UL} and n^{DL} are the present number of resources allocated for uplink and downlink communication, respectively, and n_{eq}^{UL} and n_{eq}^{DL} are the number of resources allocated for uplink and downlink communication, respectively, at equilibrium conditions.

23. A method according to any of the claims 20 to 22, **characterized in that** said gain is calculated according to:

$$g_i = \Delta y_i^{DL+} \quad \text{or} \quad g_i = \Delta y_i^{UL+}\text{, respectively,}$$

and said loss is calculated according to :

$$l_i = \sum_{j\ \left(c_{ij} > \xi,\, n_j^{UL} \geq N - n_i^{DL}\right)} \Delta y_j^{UL-} \quad \text{or} \quad l_i = \sum_{j\ \left(c_{ij} > \xi,\, n_j^{DL} \geq N - n_i^{UL}\right)} \Delta y_j^{DL-}\text{, respectively,}$$

whereby a total gain G_i is calculated as:

$$G_i = g_i - l_i\,.$$

24. A method for adaptive examination of resources for uplink/downlink traffic in a cellular communication system (10, 44), comprising the step of:

obtaining connectivity relations (c_{ij}) between cells (12) in said cellular communication system (10,44),

characterized by the further steps of;

obtaining performance data (y_j) for a number of uplink/downlink allocation configurations, for each cell in a first set of cells in said cellular communication system (10, 44), based on present traffic demands regarding

uplink and downlink traffic, said uplink/downlink allocation configurations comprising resources allocated for uplink communication (24), downlink communication (22) or barred (20) for any communication, said first set of cells comprising at least two cells; and

examining the existence of an adapted uplink/downlink allocation configuration of a second set of cells, being a subset of said first set, based on said determined connectivity relations (c_{ij}) and said determined performance data (y_j), with which:

each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) indicating interference of an acceptable level; and

the total performance of the adapted uplink/downlink allocation configuration exceeds the total performance of the original uplink/downlink allocation configuration for said second set.

25. A method according to claim 24, **characterized in that** said step of examining comprises examining the existence of an adapted uplink/downlink allocation configuration in which each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) smaller or equal to a first threshold value ξ.

26. A method according to claim 25, **characterized in that** a first resource in a cell in said adapted uplink/downlink allocation configuration, which cell has connectivity relations (c_{ij}) to other cells that are larger than said first threshold ξ, at least two of said other cells having said first resource allocated for communication in opposite directions, is barred for any communication.

27. A method according to claim 25 or 26, **characterized in that** said first threshold ξ is zero.

28. A method according to any of the claims 25 to 27, **characterized in that**, for each cell, the magnitude of the difference between the number of resources allocated for uplink communication (n^{UL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one, and the magnitude of the difference between the number of resources allocated for downlink communication (n^{DL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one.

29. A method according to any of the claims 25 to 28, **characterized in that** said steps are repeated intermittently.

30. A method according to any of the claims 25 to 29, **characterized in that** said examining step is performed if, for any cell in said first set, a gain g_i calculated from the performance data (y_j) of the existing uplink/downlink allocation configuration and the performance data (y_j) of any other uplink/downlink allocation configuration, exceeds a first amount ζ.

31. A method according to claim 30, **characterized in that** said first amount ζ is zero.

32. A method according to any of the claims 25 to 31, **characterized in that** said performance data (y_j) for each cell comprises performance indices for present uplink/downlink allocation configuration y^0, for an uplink/downlink allocation configuration of one additional resource allocated for uplink communication y^{UL+}, for an uplink/downlink allocation configuration of one less resource allocated for uplink communication y^{UL-}, for an uplink/downlink allocation configuration of one additional resource allocated for downlink communication y^{DL+}, and for an uplink/downlink allocation configuration of one less resource allocated for downlink communication y^{DL-} or data derivable therefrom.

33. A method according to claim 32, **characterized in that** said examining step is performed if, for any cell in said third set, a gain g_i calculated as the difference between the performance index y^{UL+} or y^{DL+} and the performance index y^0, exceeds a first amount ζ.

34. A method according to claim 33, **characterized in that** said examining step further comprises the steps of:

if y^{UL+} exceeds y^0:

calculating the gain g_i for changing the allocation for a resource m for said i:th cell to uplink as the difference between the performance index y^{UL+} and the performance index y^0;

calculating a loss l_i for barring resource m of all cells having a connectivity relation (c_{ij}) larger than said first threshold value ξ and having a downlink allocation as the sum of loss terms comprising the differences between the performance index y^0 and the performance index y^{DL-} for such cells; and

examining if said gain is larger than said loss; and

if y^{DL+} exceeds y^0:

calculating the gain g_i for changing the allocation for a resource m for said i:th cell to uplink as the difference between the performance index y^{DL+} and the performance index y^0;

calculating a loss l_i for barring resource m of all cells having a connectivity relation (c_{ij}) larger than said first threshold value ξ and having a downlink allocation as the sum of loss terms comprising the differences between the performance index y^0 and performance index y^{UL-} the for such cells and

examining if said gain is larger than said loss.

35. A method according to claim 33 or 34, **characterized in that** said performance data (y_j) also include priority factors for each cell.

36. A method according to claim 33, 34 or 35, **characterized in that** said performance data (y_j) also depends on $\Delta n^{UL} = \left|n^{UL} - n_{eq}^{UL}\right|$ and $\Delta n^{DL} = \left|n^{DL} - n_{eq}^{DL}\right|$, where n^{UL} and n^{DL} are the present number of resources allocated for uplink and downlink communication, respectively, and n_{eq}^{UL} and n_{eq}^{DL} are the number of resources allocated for uplink and downlink communication, respectively, at equilibrium conditions.

37. A method according to any of the claims 33 to 36, **characterized in that** said gain is calculated according to:

$$g_i = \Delta y_i^{DL+} \quad \text{or} \quad g_i = \Delta y_i^{UL+}, \text{ respectively,}$$

and said loss is calculated according to :

$$l_i = \sum_{j\ \left(c_{ij} > \xi, n_j^{UL} \geq N - n_i^{DL}\right)} \Delta y_j^{UL-} \quad \text{or} \quad l_i = \sum_{j\ \left(c_{ij} > \xi, n_j^{DL} \geq N - n_i^{UL}\right)} \Delta y_j^{DL-}, \text{ respectively,}$$

whereby a total gain G_i is calculated as:

$$G_i = g_i - l_i .$$

38. A cellular communication system (10, 44), comprising:

a number of cells (12), having a base station (34) comprising means for communication with mobile units (36); and

means for determining connectivity relations (c_{ij}) between cells (12) in said cellular communication system (10, 44),

characterized by:

means for determining performance data (y_j) for a number of uplink/downlink allocation configurations, for each cell in a first set of cells in said cellular communication system (10, 44), based on present traffic demands regarding uplink and downlink traffic, said uplink/downlink allocation configurations comprising resources allocated for uplink

communication (24), downlink communication (22) or barred (20) for any communication, said first set of cells comprising at least two cells;

means for examining the existence of an adapted uplink/downlink allocation configuration of a second set of cells, being a subset of said first set, based on said determined connectivity relations (c_{ij}) and said determined performance data (y_j), with which:

each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) indicating interference of an acceptable level; and

the total performance of the adapted uplink/downlink allocation configuration exceeds the total performance of the original uplink/downlink allocation configuration for said second set; and

means for changing the uplink/downlink allocation configuration of said second set accordingly, if said adapted uplink/downlink allocation configuration exists.

39. A system according to claim 38, **characterized in that** said means for examining comprises means for examining the existence of an adapted uplink/downlink allocation configuration in which each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) smaller or equal to a first threshold value ξ.

40. A system according to claim 39, **characterized in that** a first resource in a cell in said adapted uplink/downlink allocation configuration, which cell has connectivity relations (c_{ij}) to other cells that are larger than said first threshold ξ, at least two of said other cells having said first resource allocated for communication in opposite directions, is barred for any communication.

41. A system according to claim 39 or 40, **characterized in that** said first threshold ξ is zero.

42. A system according to any of the claims 39 to 41, **characterized in that**, for each cell, the magnitude of the difference between the number of resources allocated for uplink communication (n^{UL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one, and the magnitude of the difference between the number of resources allocated for downlink communication (n^{DL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one.

43. A system according to any of the claims 39 to 42, **characterized by** means for initializing said means for examining, said means for initializing comprising means for comparing the performance data (y_j) of the existing uplink/downlink allocation configuration and the performance data (y_j) of any other uplink/downlink allocation configuration.

44. A system according to any of the claims 39 to 43, **characterized by**:

centralized allocation means (46), comprising said means for examining;

communication means (48) between said means for determining connectivity relations and said means for determining performance data and said centralized allocation means (46);

means for distributing allocation demands from said centralized allocation means (46) to each individual cell;

whereby each individual cell comprises means for performing uplink/downlink allocation configuration change.

45. A system according to any of the claims 39 to 43, **characterized by**:

communication means (52) between a cell number i (50) and a third set of cells, comprising said i:th cell (50) and all cells having a connectivity relation (c_{ij}) with said i:th cell (50) exceeding said first threshold value ξ, for

communication of said determined connectivity relations (c_{ij}) and said determined performance data (y_j) related to the cells in said third set of cells;

whereby said i:th cell (50) said comprises said means for examining;

means for distributing allocation demands (52) from said i:th cell (50) to all other cells in said third set of cells;

whereby each individual cell comprises means for performing uplink/downlink allocation configuration change.

46. A system according to claim 45, **characterized in that** said means for determining connectivity relations provides a connectivity matrix, where each element c_{kj} indicates the interference of communication within cell k caused by communication within cell j.

47. A system according to claim 45 or 46, **characterized in that** said means for determining performance data comprises means for calculating a measure of at least one of the properties in the list of:

transmission delay,
cell throughput,
transmission buffer length, and
blocking rate.

48. A system according to claim 47, **characterized in that** said performance data is further dependent of at least one transmission quality measure.

49. A device for adaptive examination of resources for uplink/downlink traffic in a cellular communication system (10, 44), comprising:

means for obtaining connectivity relations (c_{ij}) between cells (12) in said cellular communication system,

characterized by:

means for obtaining performance data (y_j) for a number of uplink/downlink allocation configurations, for each cell in a first set of cells in said cellular communication system (10, 44), based on present traffic

demands regarding uplink and downlink traffic, said uplink/downlink allocation configurations comprising resources allocated for uplink communication (24), downlink communication (22) or barred (20) for any communication, said first set of cells comprising at least two cells; and

means for examining the existence of an adapted uplink/downlink allocation configuration of a second set of cells, being a subset of said first set, based on said determined connectivity relations (c_{ij}) and said determined performance data (y_j), with which:

each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) indicating interference of an acceptable level; and

the total performance of the adapted uplink/downlink allocation configuration exceeds the total performance of the original uplink/downlink allocation configuration for said second set.

50. A device according to claim 49, **characterized in that** said means for examining comprises means for examining the existence of an adapted uplink/downlink allocation configuration in which each two cells in said cellular communication system, having an uplink (24) and downlink (22) allocation, respectively, for any common resource, have a connectivity relation (c_{ij}) smaller or equal to a first threshold value ξ.

51. A device according to claim 50, **characterized in that** a first resource in a cell in said adapted uplink/downlink allocation configuration, which cell has connectivity relations (c_{ij}) to other cells that are larger than said first threshold ξ, at least two of said other cells having said first resource allocated for communication in opposite directions, is barred for any communication.

52. A device according to claims 50 or 51, **characterized in that** said first threshold ξ is zero.

53. A device according to any of the claims 50 to 52, **characterized in that**, for each cell, the magnitude of the difference between the number of resources allocated for uplink communication (n^{UL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one, and the magnitude of the difference between the number of resources allocated for downlink communication (n^{DL}) in said adapted uplink/downlink allocation configuration and in said original uplink/downlink allocation configuration is less or equal to one.

54. A device according to any of the claims 50 to 53, **characterized by** means for initializing said means for examining, said means for initializing comprising means for comparing the performance data (y_j) of the existing uplink/downlink allocation configuration and the performance data (y_j) of any other uplink/downlink allocation configuration.

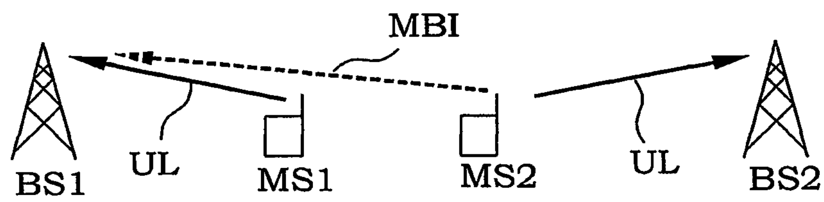

Fig. 1a

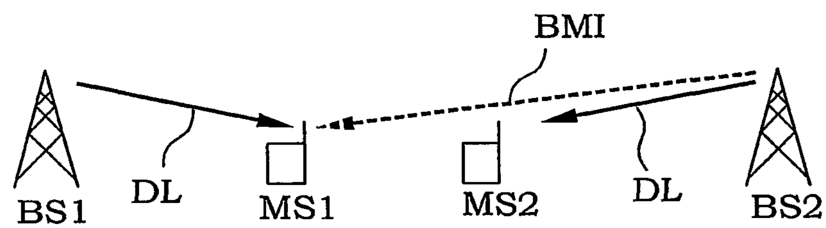

Fig. 1b

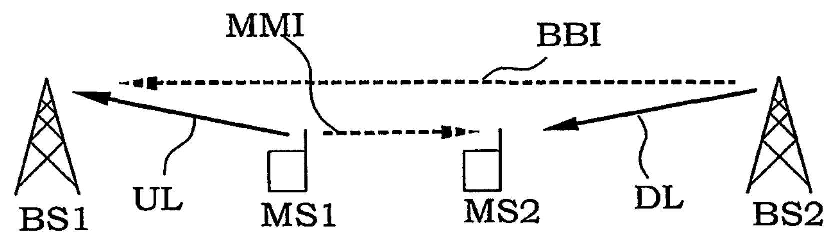

Fig. 1c

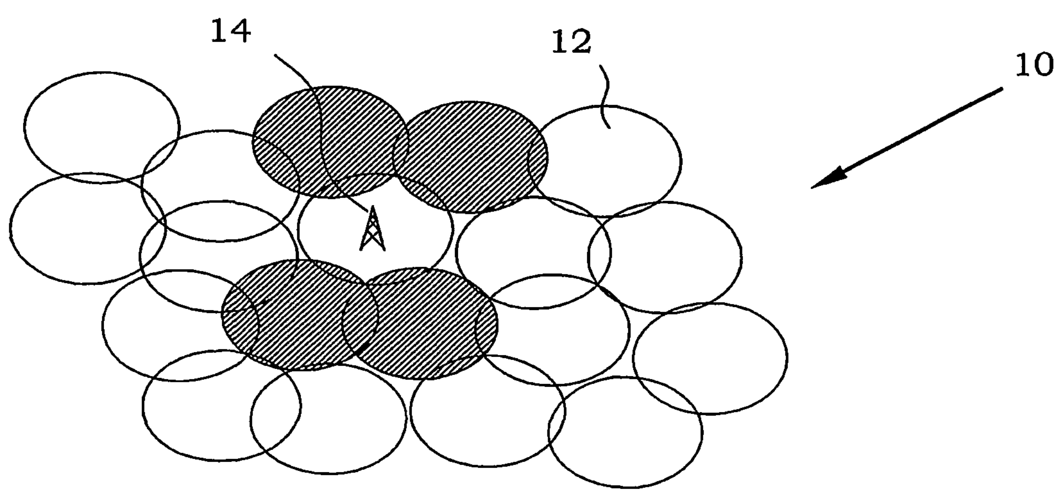

Fig. 2

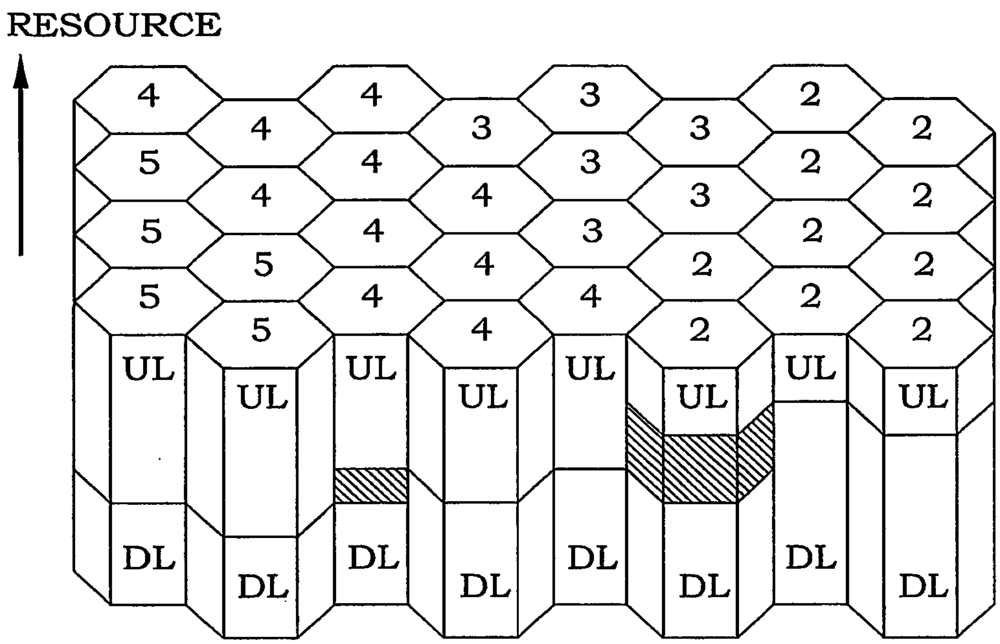
RESOURCE
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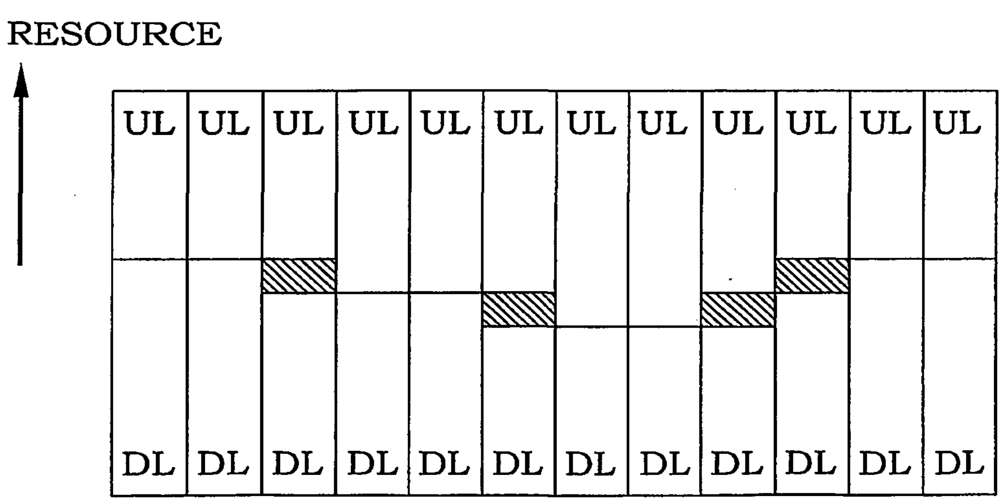
Fig. 3


RESOURCE
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DL DL DL DL DL DL DL DL DL DL DL DL

Fig. 4

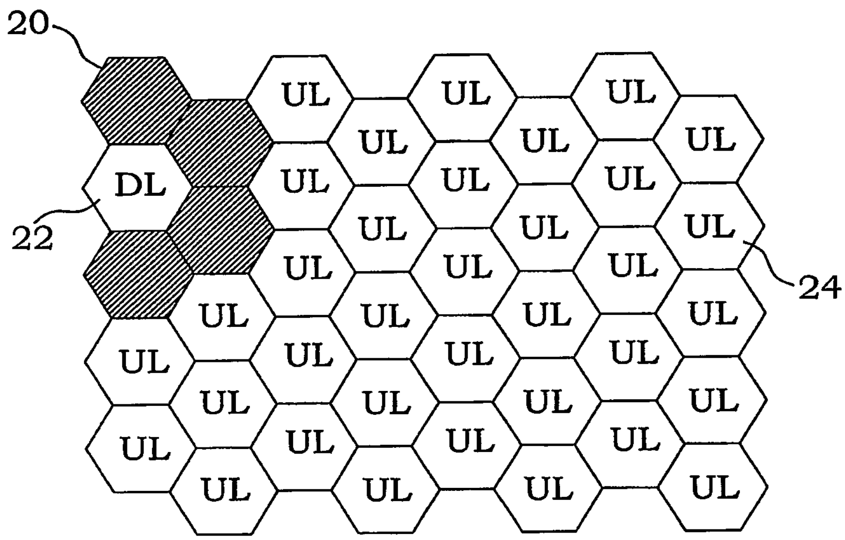


Fig. 5a

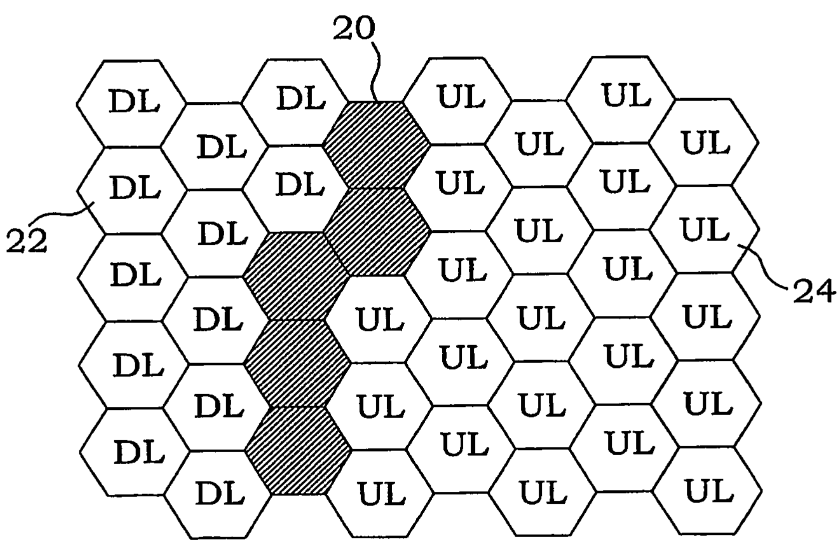
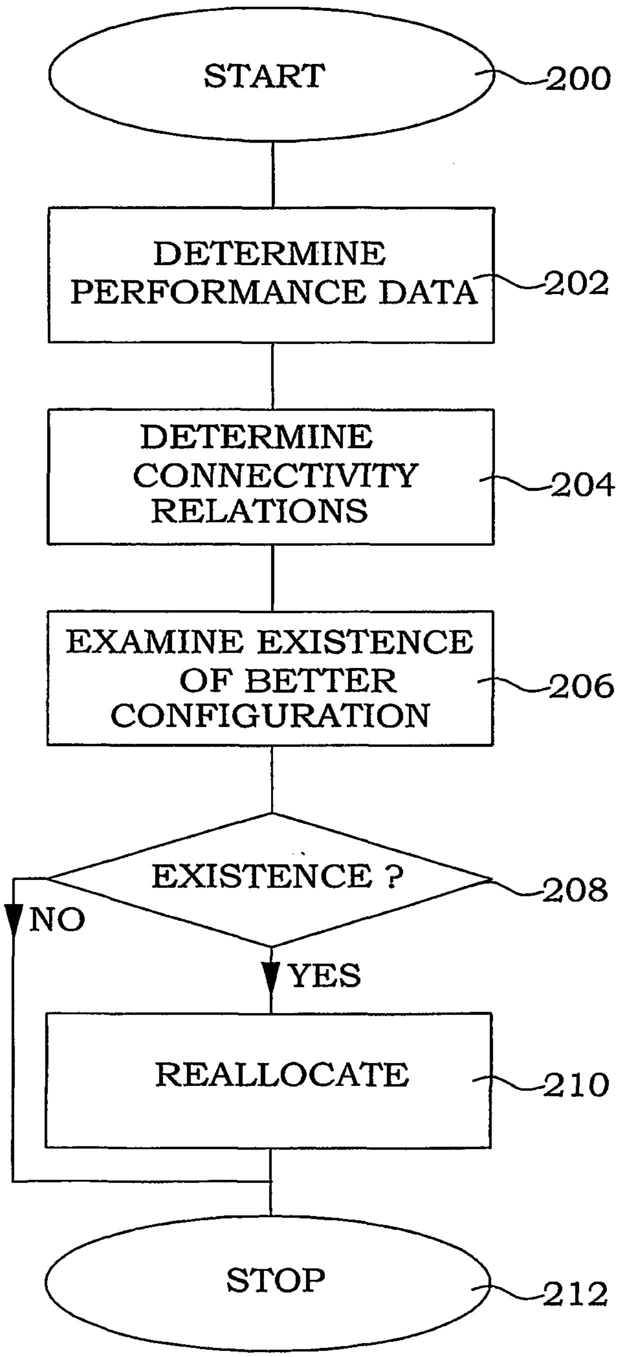


Fig. 5b


START
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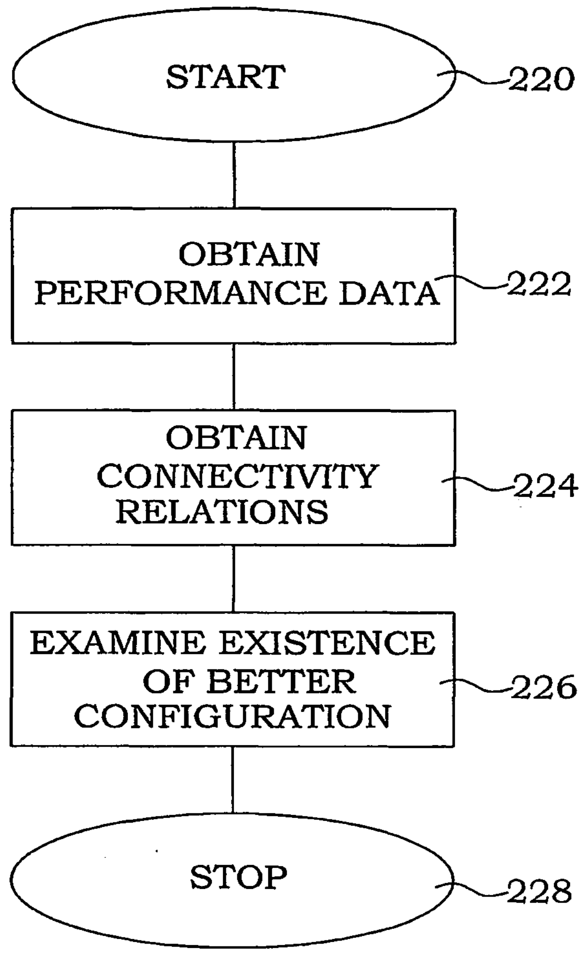
DETERMINE PERFORMANCE DATA
202
DETERMINE CONNECTIVITY RELATIONS
204
EXAMINE EXISTENCE OF BETTER CONFIGURATION
206
EXISTENCE ?
208
NO
YES
REALLOCATE
210
STOP
212

Fig. 6a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OBTAIN CONNECTIVITY RELATIONS
224
EXAMINE EXISTENCE OF BETTER CONFIGURATION
226
STOP
228

Fig. 6b

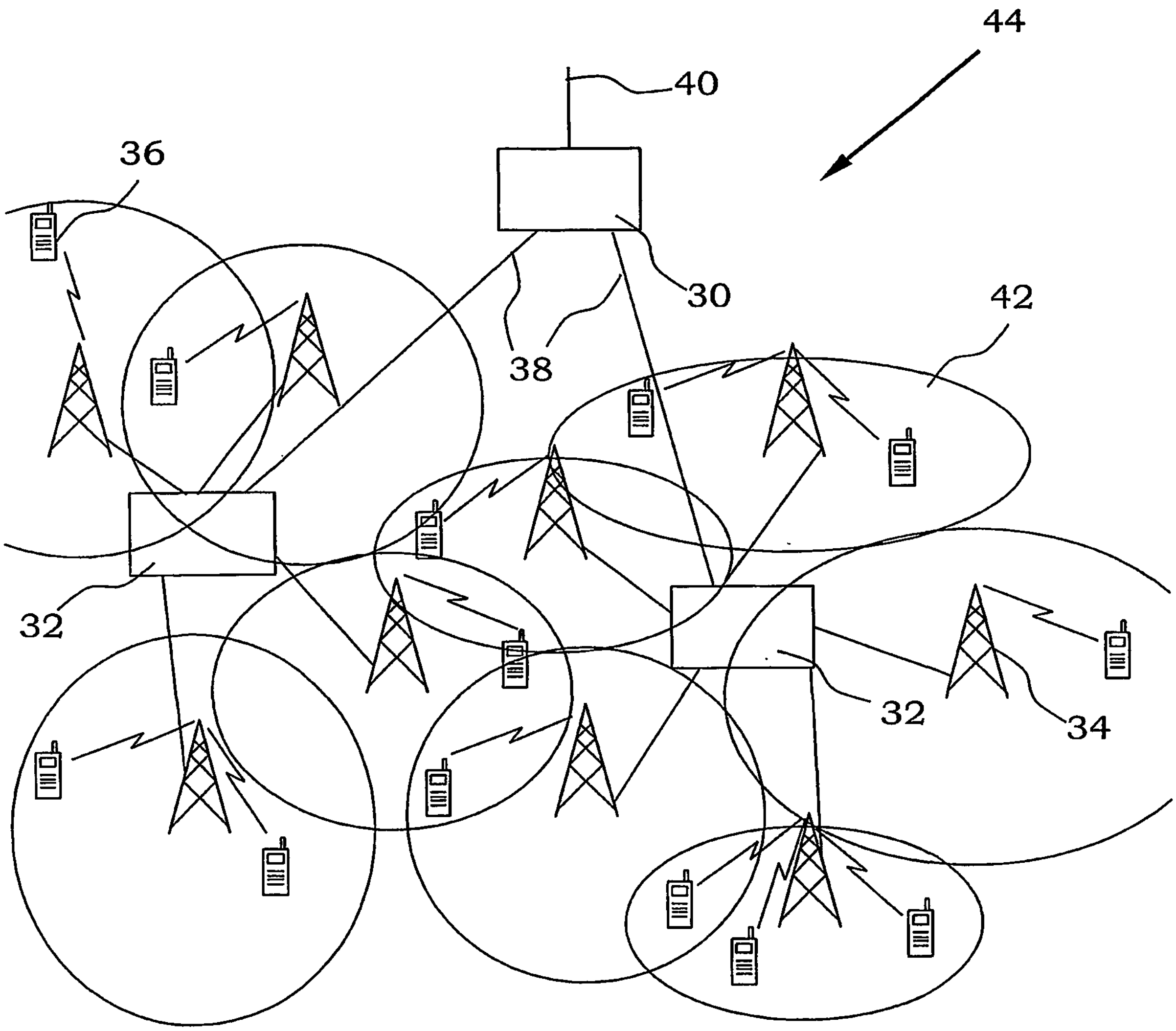

Fig. 7

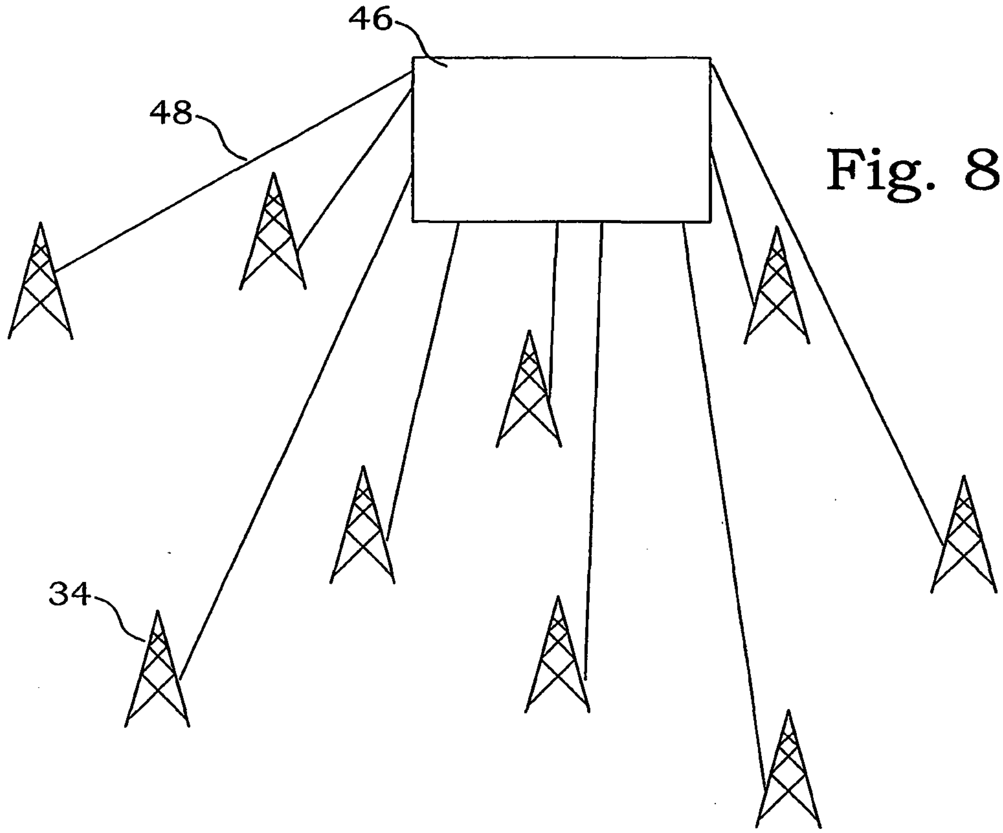

Fig. 8a

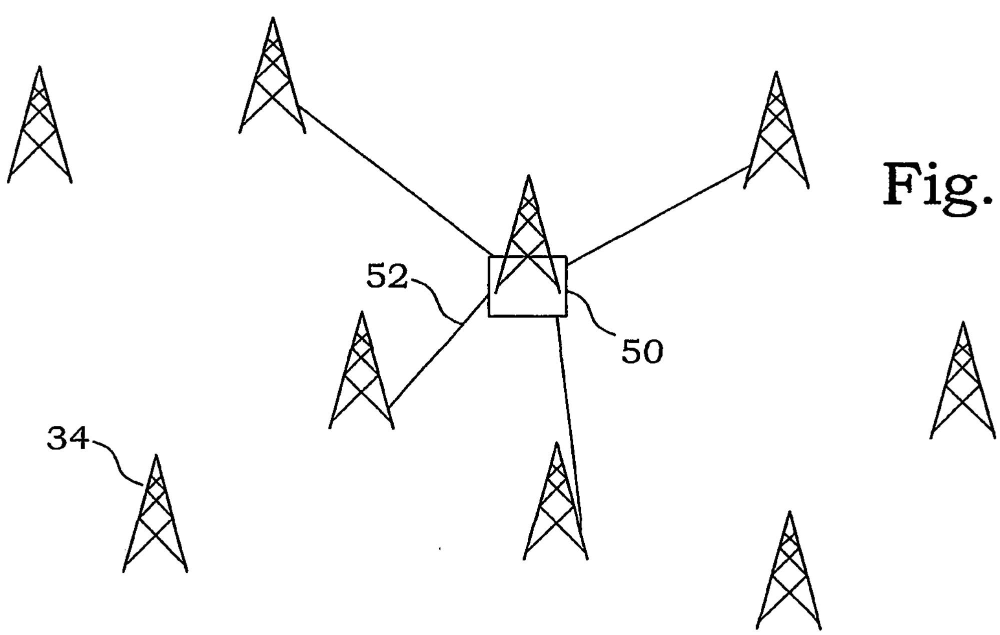

Fig. 8b

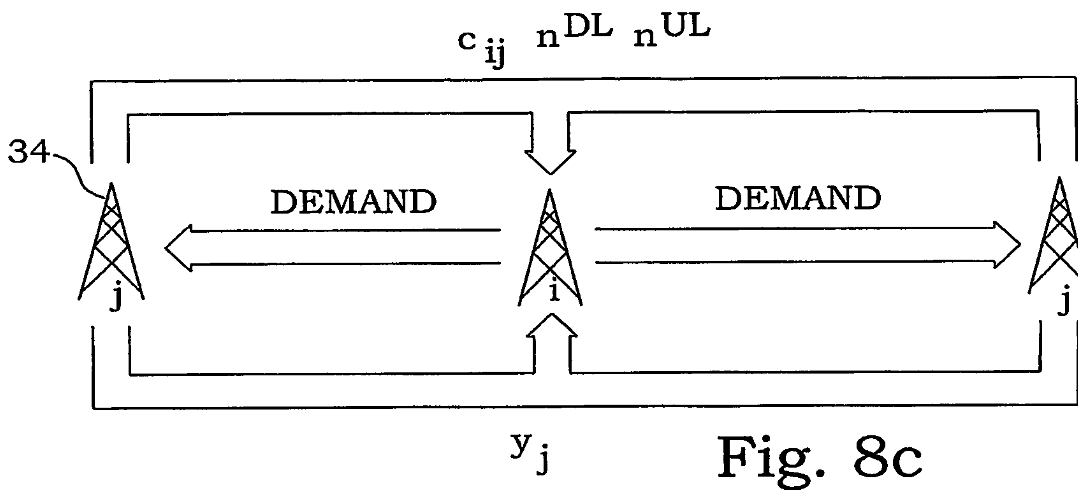

Fig. 8c

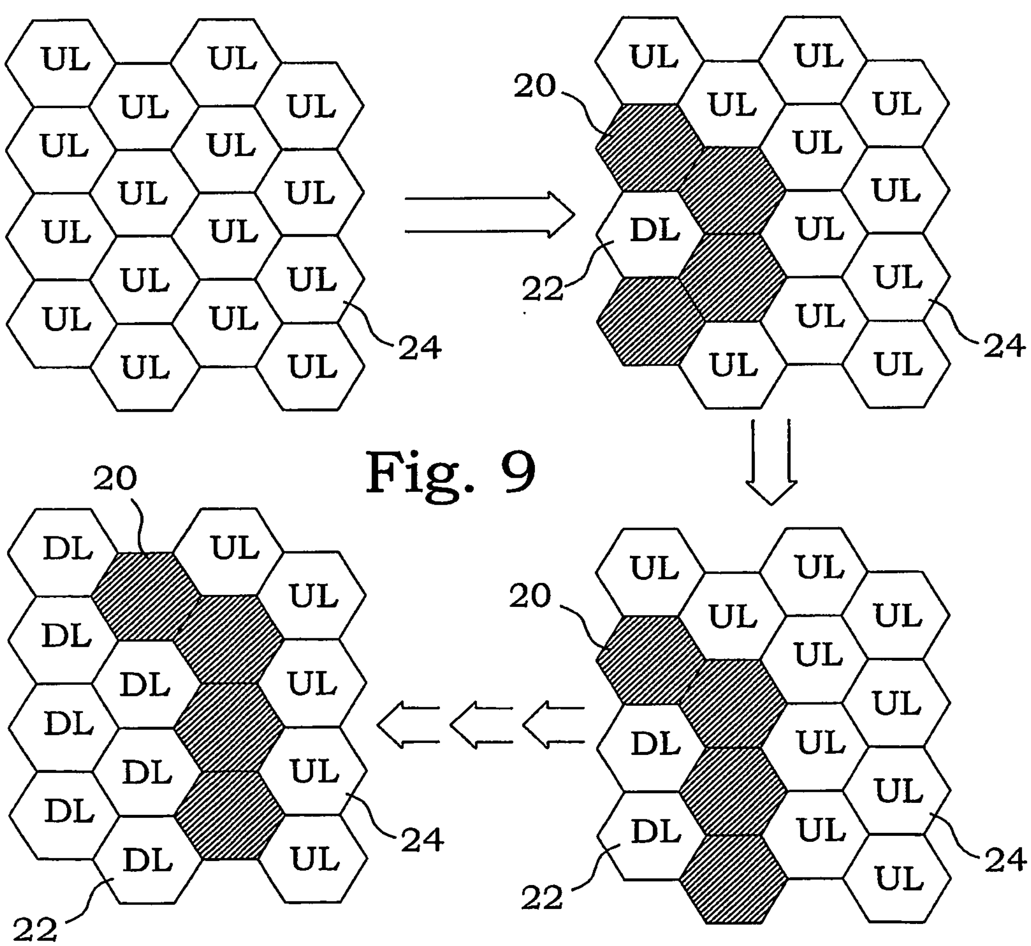

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01356

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 7/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5157709 A (Y. OHTERU), 20 October 1992 (20.10.92), column 1, line 53 - column 2, line 13; column 3, line 33 - column 5, line 35 --	1-54
A	US 5475868 A (J.M. DUQUE-ANTON ET AL.), 12 December 1995 (12.12.95), column 2, line 38 - column 3, line 17; column 3, line 64 - column 4, line 41; column 5, line 49 - line 54, column 7, line 53 - column 9, line 58 --	1-54
A	US 5594720 A (H.C. PAPADOPOULOS ET AL.), 14 January 1997 (14.01.97), column 7, line 46 - column 11, line 24, abstract --	1-54

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2001	11 -10- 2001

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Bo Gustavsson/AE Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/01356

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6023622 A (J. PLASCHKE ET AL.), 8 February 2000 (08.02.00), see the whole document --	1-54
A	US 6052593 A (V. GUIMONT ET AL.), 18 April 2000 (18.04.00), column 4, line 41 - column 6, line 25; column 9, line 29 - column 10, line 4; column 11, line 29 - column 12, line 40, column 14, line 38 - line 64 -- --------	1-54

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 01/01356

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US	5157709	A	20/10/92	GB	2234142	A,B	23/01/91
				GB	9011968	D	00/00/00
				JP	2312492	A	27/12/90
US	5475868	A	12/12/95	AU	670955	B	08/08/96
				AU	4433993	A	17/02/94
				CN	1048139	B	05/01/00
				CN	1086363	A	04/05/94
				DE	4225688	A	10/02/94
				DE	59309538	D	00/00/00
				EP	0585994	A,B	09/03/94
				JP	7007764	A	10/01/95
				DE	4303999	A	18/08/94
US	5594720	A	14/01/97	CA	2162753	A	28/06/96
				EP	0720405	A	03/07/96
				JP	8289360	A	01/11/96
				CA	2135950	A	25/05/95
				EP	0654916	A	24/05/95
				FI	945507	A	25/05/95
				JP	7203545	A	04/08/95
				NO	944404	A	26/05/95
				US	5420851	A	30/05/95
				US	5602836	A	11/02/97
US	6023622	A	08/02/00	NONE			
US	6052593	A	18/04/00	AU	7460398	A	27/11/98
				BR	9809204	A	27/06/00
				CN	1262852	T	09/08/00
				DE	19882377	T	31/05/00
				GB	2341295	A	08/03/00
				GB	9926451	D	00/00/00
				WO	9851101	A	12/11/98